Efflorescence

WHAT IS EFFLORESCENCE?

Efflorescence in concrete units is usually observed as a white deposit on the surface. This deposit can occur as a slight haze up to a crusty layer. Efflorescence is not a structural problem, it does not affect concrete strength or durability. But it is unsightly and lowers the perceived value of the concrete.

Efflorescence is usually composed of salts that are deposited on a concrete surface. It's worth noting that any concrete product that contains cement has the potential to produce efflorescence. There are four factors that combine to produce efflorescence, and they can occur during production, or once the units are installed on the jobsite. In this article, we will focus on what concrete producers can do to limit efflorescence.

THE FOUR FACTORS

1. A source of soluble salts - Portland Cement
2. Sufficient water to dissolve the salts
3. Path for the salt solution to migrate to the surface
4. Driving force to move the salt solution through the pathway

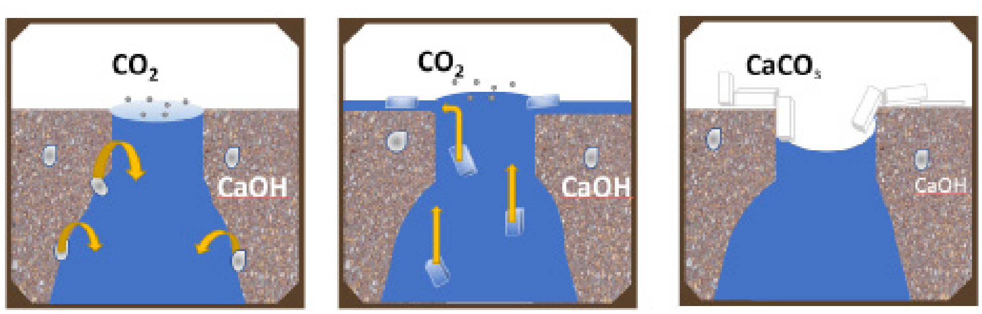
1. A SOURCE OF SOLUBLE SALTS

As you know, there's a lot of chemistry involved in concrete, so we have to get into some chemical reactions to understand what's going on. When water is added to Portland cement in the mixer, a chemical reaction called hydration occurs. Cement hydration is what causes concrete to harden and gain strength, so it's very important we understand hydration and maximize it.

The hydration reaction between cement and water forms calcium silicate hydrate (CSH) or "good" gel. This is the glue that hardens and holds concrete together. Unfortunately, the reaction is not very efficient, and a by-product called calcium hydroxide, a "bad" gel, is also formed.

One way to limit calcium hydroxide is to use pozzolans such as fly ash or slag to replace some of the cement. Fly ash and slag are able to react with calcium hydroxide, and this reaction produces more CSH gel, which is what we want. Efflorescence can also result from other soluble salts, called alkalies, usually found in the aggregates.

HOW EFFLORESCENCE HAPPENS



Calcium Hydroxide (free lime salts) particles dissolve into water in voids within the concrete matrix

Over time the water and dissolved salts migrate back to the concrete surface

The water evaporates leaving white calcium carbonate $CaCo_3$ deposits on the surface

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2. SUFFICIENT WATER TO DISSOLVE THE SALTS

During mixing: It is very important for concrete strength and durability that there is sufficient water available during mixing to hydrate the cement particles properly. Therefore, maximizing water during mixing is highly desirable. Adding as much water as possible short of pulling, picking or slumping during mixing will lead to products with higher strength and lower absorption.

After mixing: Concern over excessive water in the units comes into play after mixing, when the concrete products reach the curing stage - in the kiln or out in the yard.

Once the units are in the yard, rain and condensation can penetrate into the units, creating excess moisture conditions. Units that are exposed to repeated cycles of wetting and drying, such as during a wet spring or fall, may have increased potential for efflorescence.

3. PATHWAYS FOR SALT MIGRATION

All manufactured concrete products have a network of interconnected voids. Connected voids serve as pathways for moisture migration into and out of the concrete unit. Voids can be minimized but not eliminated. Even if you have the best mix design, materials, equipment and compaction possible, there will still be voids and pathways for salt solutions to migrate to the surface.

These pathways can be reduced by making the concrete more dense, and thus less able to absorb water. Admixtures, including water repellents and densifiers, can aid in limiting water penetration.

Concrete density can be optimized with mix design programs that analyze aggregate blends to find the best particle packing solution. Using as much water during production as possible helps lubricate the mix, and hydrate the cement. On the machine side, it is important to feed, fill and compact a mix into the molds properly to achieve a dense concrete matrix.

4. DRIVING FORCES TO MOVE THE SALT SOLUTION

When two things occur in different conditions (for example one hot and one cold), the environment will try to find balance between the two situations, and will react to reach the middle or equilibrium. This is a driving force. Driving forces will try to balance humidity and temperature in a concrete unit with ambient conditions. This may cause moisture in the unit that contains the calcium hydroxide salt solution to move to the surface of the concrete.

During curing and storage of concrete units, many common practices can cause a driving force to occur. These include:

1. Exposing units to differences in humidity and temperature between the units and their environment. For example, kilns with very high humidity will cause units to absorb excess moisture.
2. When units are moved from a heated kiln environment to a cold yard without allowing the units time for their internal temperature to lower and match that of the outside environment.

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Factors that create driving forces that can affect concrete products	What producers can do to help reduce driving forces and limit efflorescence
Units made too cold: concrete internal temperatures below 50° F (10° C) that may occur when kilns are not heated or not full.	Reduce pozzolan use and consider using an accelerator admixture to speed hydration.
Units made too hot: Concrete temperatures above 90° F (30° C). Hot materials drive out water and the mix does not compact well, leading to more voids.	Lower the temperature of the concrete, use cold water or retarding admixture.
Very high humidity in the kiln. For example, water dripping from the ceiling or racks, may be a sign of too high humidity.	Monitor and control humidity levels in the kiln.
Moving products from kiln to yard too quickly. For example, placing steaming hot units outside in cooler weather.	Open and vent the kiln to allow temperature and humidity to come closer to ambient conditions. Allow units time to adjust to ambient temperature before moving into the yard.
In the yard, under certain conditions, evaporation from unit surfaces leads to a difference in moisture between the surface and the interior of a unit. For example, evaporation will increase in sunny, windy conditions.	Use topsheets on pallets to limit evaporation.
Cube efflorescence: Typically appears as streaks, or a ring or halo on the top layer of the cube. Direct sunlight on stretch-wrapped cubes may create a “greenhouse effect”, when trapped warm air and water vapor rise in the cube, and moisture condenses on the interior of the plastic sheeting. Water then pools on the top layer of the CMU or blotches in areas where water is slow to evaporate. Repeated wetting and drying of the top layer raises the potential for efflorescence.	Replace stretch wrap with topsheets that allow excess moisture to escape.

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